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# Harmonic radiation from u.h.f. television transmitting stations

## No. 1969/37

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

RESEARCH DEPARTMENT

# HARMONIC RADIATION FROM U.H.F. TELEVISION TRANSMITTING STATIONS

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Research Department Report No. **1969/37**

# HARMONIC RADIATION FROM U.H.F. TELEVISION TRANSMITTING STATIONS

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# HARMONIC RADIATION FROM U.H.F. TELEVISION TRANSMITTING STATIONS

## SUMMARY

*This report describes measurements of the levels of second and third harmonic signals at Crystal Palace (Channel 33) and of second harmonic signals at Emley Moor (Channel 51), both in the feeders and radiated from the aerial. The radiated levels were so low that they could be measured only within very close range from the transmitter.*

*The general harmonic level in the feeders was about –70 dB to –90 dB whilst that measured at close range was about –95 dB (relative to the level of the fundamental in all cases). The results show evidence of harmonic generation at about these levels in the feeders and aerials at Crystal Palace.*

*It is estimated that the second harmonic of the Emley Moor transmission is unlikely to cause harmful interference at Jodrell Bank and, in any case, it is considered that further reduction in the harmonic level there may not be technically feasible.*

## 1. INTRODUCTION

In addition to the wanted transmission, a television or sound transmitter generates low-level signals at several other frequencies in the radio spectrum, some of which may constitute potential sources of interference. From the point of view of most radio users in other bands these unwanted signals occur at harmless levels but, in the case of u.h.f. television transmitters operating in certain channels, second or third harmonic signals may fall in bands allocated to radio astronomy where much lower levels of interference are harmful. As it is not possible to predict these levels, measurements were made at Crystal Palace and Emley Moor to assess the magnitudes of these unwanted signals.

Recommendations for the suppression of out-of-band signals[1] refer only to the output port of the transmitter. A knowledge of harmonic levels at only the output port is usually inadequate for two reasons:

(a) The attenuation of the feeder system and the radiation characteristics of the aerial may not be known at the harmonic frequency.
(b) At the low levels under consideration, the generation of harmonics by non-linearities in the feeders and aerial cannot be ignored.

If possible, therefore, measurements should be made of the radiated harmonic levels.

Measurements were made at Crystal Palace (Channel 33) and Emley Moor (Channel 51) both in the feeders and at points a few miles away from the stations. In view of the generally difficult nature of the investigation, the first series of measurements at Crystal Palace was performed in order to establish measurement techniques. Emley Moor was chosen for the second series of measurements because the second harmonic of Channel 51 (BBC-2) there might cause interference at the Jodrell Bank telescope.

At the time the measurements described in this report were made (March–June 1968), the aerial at Crystal Palace comprised 30 tiers of skewed Yagis at 194 m a.g.l.; the aerial at Emley Moor comprised eight tiers of panels at 370 m a.g.l.[2] Neither aerial is now in existence.

## 2. METHODS OF MEASUREMENT

### 2.1. Levels in the Feeders

These measurements were made at the outputs of existing directional couplers in the feeder and combiner assemblies at the transmitter outputs. As a preliminary, the couplers were calibrated at the fundamental and harmonic frequencies. The measuring arrangement employed is shown schematically in Fig. 1. A well-screened receiver was used and the input to it from the coupler was fed through a high-pass filter and a tunable band-pass filter in order to suppress the fundamental signal. The local-oscillator frequency of the receiver was indicated by a counter which, in conjunction with the tunable filter, enabled the signal being measured to be identified. The receiver indications were calibrated by substitution with a signal generator. There was a risk that the harmonic being measured was being partly generated from the fundamental either in the terminating load of the coupler or in the receiver itself. (In the arrangement shown in Fig. 1, signal at the fundamental frequency reaches the coupler load after reflection from the high-pass filter.) By inserting a 10 dB attenuator immediately before the high-pass filter the level of fundamental signal into the coupler load was reduced by 20 dB, and into the receiver by 10 dB. When the attenuator was inserted it was found that the measured ratios of harmonic to fundamental remained unchanged in all cases. It was therefore concluded that harmonic generation both in the couplers and in the receiver was insignificant. Careful attention was also paid to screening in order to make negligible the effect of the high field strengths existing within the transmitter buildings.

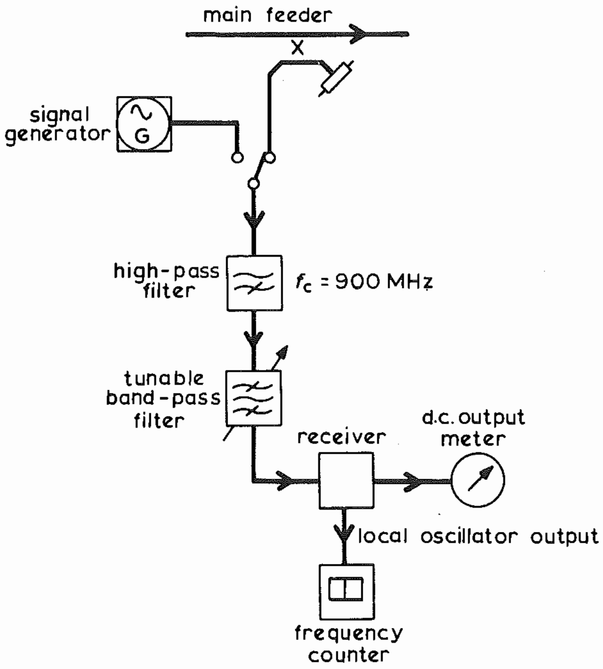

*Fig. 1 - Arrangement adopted for measuring harmonic levels in feeders*

The harmonic levels in the feeders were measured with the vision transmitter modulated at black level with synchronizing pulses; the sound transmitters were powered but not driven. Fig. 2 shows schematically the feeders and combining units at Crystal Palace and Emley Moor. The coupler outputs at which measurements were made are indicated by capital letters.

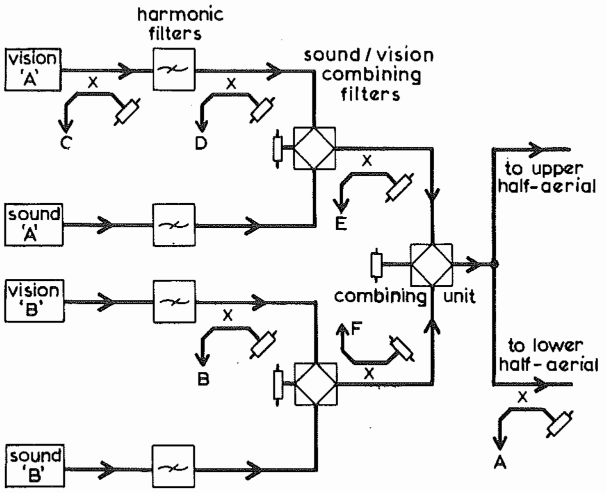

*Fig. 2 - Schematic of feeders and combining units at Crystal Palace and Emley Moor*

### 2.2. Radiated Levels

The levels of the radiated harmonics were measured using a small horn aerial connected to a special receiver.[3] The levels of the signal radiated at the fundamental frequency were measured using a Yagi aerial connected to a standard field-strength measuring receiver. In order to operate the special receiver, the vision transmitters were modulated with a 1 kHz square wave at a peak power equal to the normal peak-sync power. The sound transmitters were powered but not driven.

The harmonics were so weak that reliable measurement was possible only within about 2 km range from the transmitting aerials. At such short range, interaction between the direct and ground-reflected signals was such as to cause the resultant field strength at the receiving aerial (at both the fundamental and the harmonic frequencies) to vary rapidly as a function of aerial height. The effect is shown in Fig. 3 which compares the measured variations with the variation that would be expected if the intervening terrain were flat and unobstructed. For each measurement, therefore, the field strength was explored over the range of aerial heights 4 m to 8 m; a mean value for the level of the harmonic signal relative to that of the fundamental was deduced. From the results shown in Fig. 3, for example, the mean value would be taken to be −100 dB. Results given in Section 3.2 of this report are mean values deduced in that way.

## 3. RESULTS

### 3.1. Levels in the Feeders

Levels of the second and third harmonic of the vision carrier, relative to the level of the fundamental, were measured at coupler A (see Fig. 2) at Crystal

### *TABLE 1*

*Levels of Second and Third Harmonics (Relative to Fundamental) Measured at Coupler A (see Fig. 2) at Crystal Palace (using Black Level with Syncs)*

| Transmitter conditions | Harmonic filter at output of Vision Transmitter B | Relative level of | |
|---|---|---|---|
| | | 2nd harmonic | 3rd harmonic |
| A and B combined | present | –86 dB | –93 dB |
| | removed | –84 dB | –90 dB |
| A only | present | – | –93·5 dB |
| B only | present | – | –93 dB |
| | removed | – | –91 dB |

Palace. Measurements were made with various combinations of the two vision transmitters, both with and without the harmonic filter at the output of vision transmitter B (see Fig. 2). The results are given in Table 1.

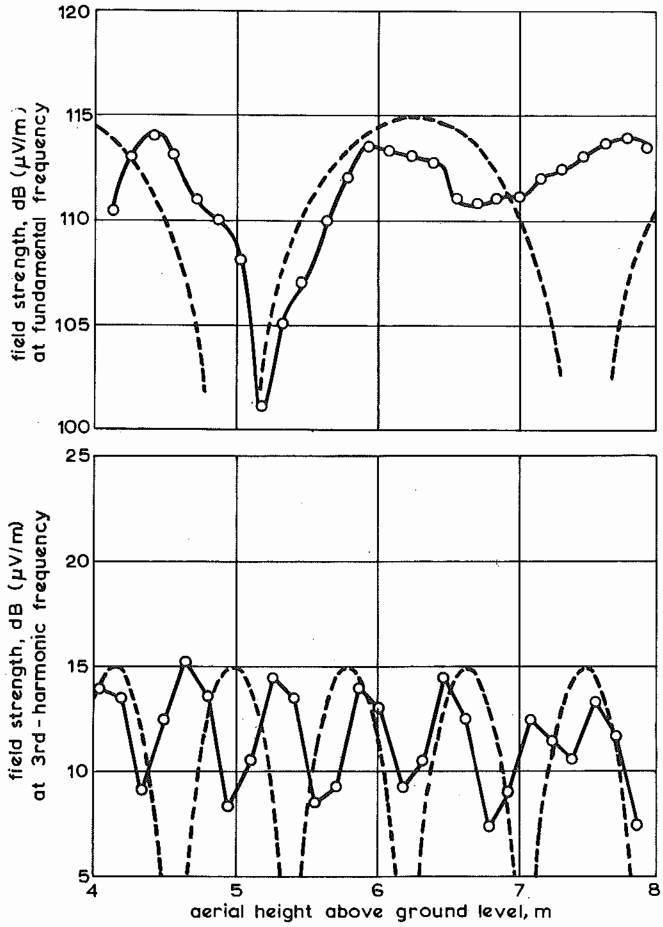

*Fig. 3 - Variation of field strength as a function of height at fundamental and third harmonic frequencies*

------- Theoretical variation assuming flat unobstructed terrain

—o—o— Measured variation

The change in level of the second and third harmonics was also measured at coupler B (see Fig. 2) with and without the harmonic filter at the output of vision transmitter B. The filter was found to reduce the level of second harmonic by more than 40 dB but to reduce the level of third harmonic by only 7 dB.

Measured between 50-ohm source and load, the filter was found to introduce 60 dB and 45 dB attenuation at the frequencies of the second and third harmonics respectively.

Levels of second harmonic of the vision carrier, relative to the level of the fundamental, were measured at couplers A, C, D, E and F (see Fig. 2) at Emley Moor. The results are given in Table 2.

### *TABLE 2*

*Levels of Second Harmonic (Relative to Fundamental) in the Feeders at Emley Moor (Using Black Level with Syncs)*

| Coupler output | Transmitter conditions | Relative level of second harmonic |
|---|---|---|
| C | A only | –8 dB |
| D | A only | –44 dB |
| E | A only | –56 dB |
| F | B only | –55 dB |
| A | A only | –79 dB |
| A | B only | –69 dB |
| A | A and B combined | –68 dB |

### 3.2. Radiated Levels

In the region of Crystal Palace the level of second harmonic radiation was found to be immeasurably small (i.e. less than about 2·5 μV/m) at all sites; the third harmonic was measurable at only the nearest site, at 2 km range from the transmitter. This site was in an urban region about 84 m a.o.d. having a line-of-sight path to the transmitting aerial along a road (Holderness Way, Norwood) flanked on both sides by houses and flats.

The mean levels (see Section 2.2) of third harmonic relative to fundamental measured at this site with various transmitter combinations are given in Table 3.

*TABLE 3*

*Radiated Levels of Third Harmonic (Relative to Fundamental) Measured at Crystal Palace (1 kHz square-wave Modulation)*

| | |
|---|---|
| Transmitters A and B combined | –94 dB |
| Transmitter A only | –97 dB |
| Transmitter B only, harmonic filter in circuit | –97 dB |
| Transmitter B only, harmonic filter removed | –95 dB |

In the region of Emley Moor the level of only the second harmonic was considered, and at sites only along the bearing of the Jodrell Bank radio-astronomy station, because the second harmonic was considered a possible source of interference to radio astronomy at Jodrell Bank. Although measurement was convenient very close to the transmitter, the results would be greatly affected by the vertical radiation pattern of the aerial and would tend to be unrepresentative. The only site at which representative measurement was possible was at 2·3 km range from the transmitter. It was an open site having a line-of-sight path to the transmitting aerial at an angle of elevation of about 3°. With both vision transmitters combined the mean level (see Section 2.2) of second harmonic relative to fundamental was –92 dB. The second harmonic was immeasurably small (i.e. less than about 2·5 μV/m) at this site when either transmitter was powered individually.

## 4. DISCUSSION OF RESULTS

The results show that the harmonic levels in the outgoing feeders were about –90 dB (relative to the fundamental) at Crystal Palace and about –70 dB at Emley Moor. At both stations these levels were achieved partly by intentional suppression due to harmonic filters and partly by fortuitous suppression in combining filters. Removing one of the harmonic filters at Crystal Palace increased the level of second harmonic in the feeder near to the transmitter by 40 dB yet it increased the harmonic level in the outgoing feeders by only 2 dB. This implies harmonic generation at a low level (i.e. at about –100 dB relative to the fundamental) in the feeders and combining equipment.

The radiated harmonic levels were about –95 dB relative to the fundamental at both Crystal Palace and Emley Moor. There is evidence of harmonic generation in the aerial system at Crystal Palace in that the relative radiated harmonic level increased by 3 dB when the two transmitters were combined. This measured level, barely above the limit of measurement set by the available equipment, is of the same order as that (–100 dB) which has been quoted as being the lowest level of harmonic radiation that can be reliably achieved.

It will be recognised that, due to the vertical radiation pattern of the aerial, the relative level of harmonic radiation may vary with range and, from that point of view, it is unfortunate that the measurements were restricted to such close range by the sensitivity of the available equipment. Nevertheless, it is of interest to estimate the resultant field strength of harmonic interference at the Jodrell Bank radio telescope on the basis of the –95 dB result. The calculated median field strength of the Emley Moor transmission at 61 m a.g.l. at Jodrell Bank is +73 dB (μV/m). It is considered that the propagation conditions of the path would not be very different at the second harmonic frequency. It is estimated that the relative level of second harmonic would, due to the radiation characteristics of the aerial, be about 10 dB less in the horizontal plane than at 3° depression (i.e. about –105 dB). The estimated median field strength of the second harmonic signal (at 1422·5 MHz) at Jodrell Bank is therefore –32 dB (μV/m). This is approximately 10 dB greater than the threshold level which, if it were continuous, has been suggested by the Post Office as being harmful to radio-astronomical observations at Jodrell Bank.

## 5. CONCLUSIONS

This report has shown that the harmonic levels in the aerial feeders were about –90 dB (relative to the fundamental) at Crystal Palace and about –70 dB at Emley Moor. There was evidence of harmonic generation (at that low level) in the feeders and combining units at Crystal Palace. This accords with previous experience at Band II transmitting stations and it confirms the view that harmonic suppression in the feeders to below –100 dB (relative to the fundamental) cannot be relied upon.

The measured radiated levels of harmonic were about –95 dB (relative to the fundamental) at both

Crystal Palace and Emley Moor. There was evidence of harmonic generation in the aerial system at Crystal Palace. Again, these results confirm the view that it may not be technically feasible to suppress unwanted radiation to below −100 dB relative to the level of the fundamental.

The sensitivity of the measuring receiver restricted the measurement of radiated harmonic levels to within about 2 km range from the transmitter. Although, due to the uncertain radiation characteristics of the aerial at second-harmonic frequencies, the radiated harmonic levels at great range cannot be reliably predicted, it is estimated that the median field strength of the interference at the Jodrell Bank radio telescope would be about −32 dB($\mu$V/m). This is approximately 100 dB below the fundamental signal. It is considered unlikely to be harmful to radio astronomical measurements but, even if it is, further suppression may not be technically feasible.

## 6. REFERENCES

1. C.C.I.R., Oslo, 1966, Recommendation 329-1, Vol. 1, p. 42.
2. U.H.F. transmitting aerial for the Emley Moor television station. BBC Research Department Report No. E-119/2, Serial No. 1966/47.
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